UNIVERSAL BATTERY CHARGER

http://sergiols.blogspot.com/

Universal Battery Charger
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Firmware Version: 1.1

Project Parameters
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Features

- Supports Pb, SLA, NiCd, NiMH, Li-Ion and LiPo batteries
- Firmware written in C compiler SDCC 2.9.0.
- Manager written in Java platform.
- Allows for charging, discharging and cycling using different cut-off sensors.
- Implements sophisticated algorithms to optimize battery life.
- High-precision measurements.
- Serial Connection.
- Optional EEPROM Memory.
- Menu system for full operation.
- Low cost

Summary

The battery charger described in this document complies with all recommendations and current design of battery chargers. This charger can charge slowly, medium or fast charge all popular battery types without hardware modifications or firmware.

Introduction

Continuous improvement in battery technology increasingly requires sophisticated algorithms to ensure quick and safe charging. Accurate monitoring of the charging process is necessary to minimize the charge time to obtain the maximum battery capacity without causing damage to them.

Basics

Charging a battery is made possible by a reversible chemical reaction that restores energy in a chemical system. According to the chemical used, the battery will have certain characteristics. When designing a charger, you must have a detailed knowledge of these specifications to prevent damage caused by overcharging.

Design Data

Programming Language	SDCC compiler, version 2.9.0
Code size	14 Kbytes
PWM Frequency	16HZ 10bits resolution
Measuring Current	Operational Amplifiers
Clock Speed	20Mhz external crystal
Communication	Serial Port
Memory	EEPROM 256kbits optional(not used in current firmware)

Battery Technology

Modern electronic devices mainly used four different rechargeable batteries:

- Lead acid (Pb / SLA)
- Nickel-cadmium (NiCd)
- Nickel-metal hydride (NiMH)
- Lithium ion (Li-Ion)
- Lithium Polymer (Li-Poly)

It is important to have some background information on these type of batteries to choose the correct battery and the charging algorithm for use.

Lead Acid (Pb / SLA)
The lead-acid batteries are used in a lot of applications where the cost is important and the space and weight. SLA are typically for UPS backup batteries and alarms. SLA batteries are charged using constant voltage, with a limitation of current to prevent overheating in the initial stage of charging. This type is the battery can be charged indefinitely, while the voltage of the cell can never exceed the manufacturer's specifications (typically 2.2V).

Nickel-cadmium (NiCd)
Nickel-cadmium batteries are relatively inexpensive, can be fully charged about 1000 times. They have a very high rate of self-discharge. The NiCd's can be damaged by abuse, if the cell's are completely discharged or the battery pack is reversed. To avoid damage been caused is the discharge of the battery pack voltage should be monitored constantly and the application should shut down when the cell voltage drops below 1V. NiCd batteries are charged with constant current. Nicad's suffer from the memory effect and should be discharged before they are charged.

Nickel Metal Hydride (NiMH)
The nickel-metal hydride batteries are widely used in portable applications under weight. Have a higher energy density than NiCd. NiMH batteries are damaged by overcharging. It is important to the accuracy of the readings to finish the charging at an accurate time. Just as NiCd, NiMH batteries are damaged by abuse. These batteries have a self-discharge rate of approximately 20% per month. As NiCd batteries, NiMH batteries are charged with constant current.

Lithium ion and lithium polymer (Li-Ion and Li-Poly)
Li-Ion batteries have an energy ratio / weight and energy / space very high compared with other types of batteries. Li-Ion batteries are charged using constant voltage, with a current limit to prevent overheating in the initial stage of charging. The charge is terminated when the current falls below current lower limit set by the manufacturer. These batteries are damaged by overcharging and may explode when overcharged.

Charging the battery safely
The modern fast chargers (for example, those charged in less than 3 hours usually within an hour) require accurate measurements of cell voltage, Charing current and temperature to achieve full charge the battery without overcharging and overheating.

Charging Methods
SLA batteries, Li-Ion and Li-Po are charged by constant voltage (and current limited) and NiCd and NiMH are charged with constant current and have different methods of termination.

Maximum charge current
The maximum charge current depends on battery capacity . The maximum charge current is normally given in amounts of battery capacity, for example, a battery with 750mAh capacity cell charged with a 750mA charge current was charged at 1C (once the battery capacity). If the load current to floating charge is set to C/40 charge current is the ability of the cell divided by 40.

Overheating
For the transfer of power to charge a battery, This energy stored in a chemical process. But not all electric power applied to the battery transformed into the battery as chemical energy. Some of the power ends as heat energy, heating up the battery. When the battery is fully charged all electric power was applied to the battery ends up as heat energy. At a rapid charge will cause rapid heating of the battery, causing damage if the charging does not stop. We monitor the temperature to complete the charging, This is an important factor in a good design of a battery charger.

Termination Methods
The data sheet suggests battery termination methods used. The use and the environment where the battery is used establishes restrictions on the choice of termination method. Sometimes it may be impractical to measure the temperature of the battery and easier measurement of voltage, or any other form. This design implements the use of drop voltage (-dV/dt) as the main method of termination, in addition to temperature and voltage as a receipt. Also supports all these other methods:

t = Time
This is one of the simplest methods to measure when charging is complete. Normally used as backup termination in fast charge and as the main method in a normal charge. Applies to all batteries.

V = Voltage
The charge is terminated when the voltage exceeds a limit. Used in combination with current constant charge. The maximum current is determined by the battery, usually 1C as was described above. The current limit is crucial to avoid damage heat to the battery if the current is very high. SLA batteries are normally charged indefinitely by establishing a maximum voltage below the current charge voltage. In principal this is used has a method and algorithm termination.

-dV/dt = Voltage Drop
This method uses the derivative negative voltage in a time interval. Used normally constant current charge. Applies to NiCd and NiMH batteries.

I = Current
The charge is terminated when the load current drops below the pre-set value. Used normally constant voltage load. Applies to SLA batteries, Li-Ion and Li-Po to finish Load the second phase, usually after the fast charge phase.

T = Temperature
The absolute temperature can be used as termination (for NiCd and NiMH), but only as termination of shelter. The burden of all batteries should end if temperature exceeds the upper limit of operation established by the manufacturer. In addition, used as a backup method to cancel the charging if the voltage drops below the safe temperature. Applies to all batteries.

dT / dt = Peak temperature
The derivative of the temperature in a time interval can be used as method a fast charge termination. According to the manufacturer's specifications (Usually 1 C / minute for NiCd batteries). Applies to NiCd and NiMH.

DT = temperature above room temperature
Terminates the load when the difference between room temperature and battery rises above a preset value. Applies to NiCd and SLA batteries as the main method or shelter.

Hardware Implementation

Power Stage
The input voltage (11 to 24v) is regulated through the voltage regulators 7805 and 7812. The 5v supply to the microcontroller 7805. The 7812 (12v) feeds power to the fan for ventilation This help to keep the charger cool

Power part.
Amplifier Formed by two mosfet's, one charging and one for discharging, the charger can handle currents of up to 5Aamps with a voltage range from 3 to 20v.

Operation
Four buttons for the management of the unit. Setting up the battery type and the charging current

Indicators
Buzzer for audible indications of completion and use of the buttons.
LCD backlight management
Red led operation for showing progress.
Yellow LED to indicate operation complete.(batteries fully charged)

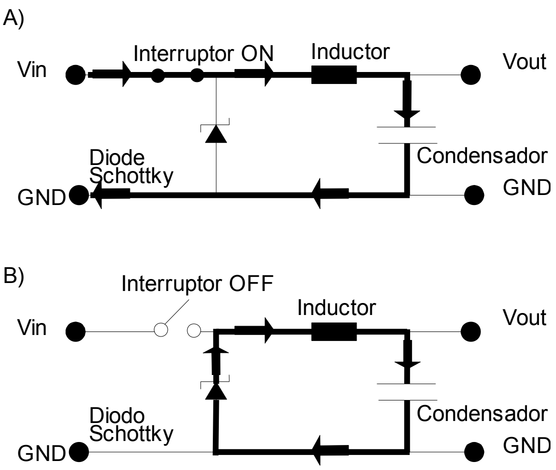
PC Interface
Connected to the UART interface can connect the PC to record the data battery during charging. The data is shown in different graphs and can be exported to spreadsheets like Excel for analysis or storage. The software runs on most operating systems.

EEPROM (optional)
It can be used to store the various cycles of loading / unloading of a battery without the use of a PC. Not implemented in firmware(future development)

ISCP
Allows the reprogramming of the microcontroller from a PC using a programmer compatible.

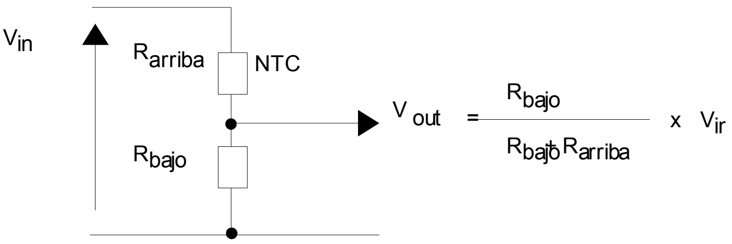
16kHz Buck Converter
The buck converter consists of a P channel MOSFET transistor driven by the PIC via a NPN bipolar transistor. The MOSFET is connected to an inductor, a diode and a capacitor (see Figure 1.) An additional diode proects the microcontroller with the battery voltage power supply is disconnected. When the MOSFET is ON (illustrated in Figure by the closed switch) current will flow as shown in Figure 1A. The capacitor entry is charged via the inductor (which is also charged). When the switch opens (Figure 1B) the inductor will try to maintain their current flow through induction voltage. The current will flow through the diode and inductor will charge into the condenser. Then cycle repeats. If the duty cycle is low, for a short time in ON and OFF a long time, the voltage will decrease. If the duty cycle increases (long ON and OFF bit) the voltage increase. A buck converter is more efficient running with a 50% duty cycle.

Figure 1: Principle of a buck converter



Battery Temperature

The temperature is measured by a negative coefficient resistor (NTC). You have approximately 10kΩ resistance value at 25C. The NTC is part of a divider voltage, which feeds the reference voltage (5V).



The resolution measured the voltage across the NTC is:

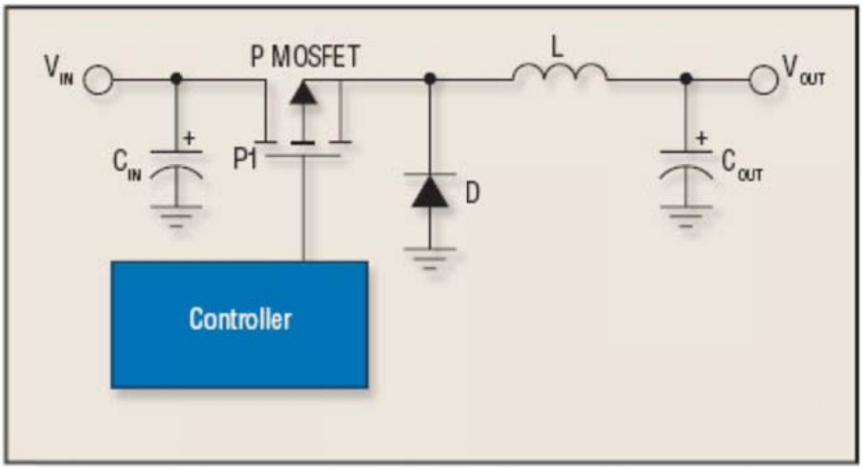
5V / 1024 = 4.88mV steps / step.

The NTC used to 25 degrees measured 10k, replacing this value in Rarriba:
Vout = (480Ω / (480Ω + 10000Ω)) * = 229.008mv 5000mv

In steps of ADC:
N = Vout / (mv / step) = 229,008 / 4.88 = 46.9

Then 25 degrees / N steps = 0533, this value, using it to determine the temperature a very basic method as the NTC resistance does not follow a linear curve, but for the purposes are practical for this application.

Design Theory
It then describes specific design theory of battery charger.



The calculation of the inductor out of the formula:

L = (Vinmax - Vout) * (Vout / Vinmax) * (1 / fsw) * (1 / (LIR * Ioutmax))
The LIR for a 70th ripple pp with a current of 1A, is equal to
LIR = 0.07 / 1 = 0.07
Then L is:

L = (24 - 1.5) * (1.5/24) * (1 / 16000) * (1 / (0.07 * 5)) = 468.75 uH

To calculate the capacitor we should take into account the voltage drop and ripple present at the output of the converter. Big and tall falls are the caused of the low ripples output capacitance. A 1000uF capacitor provides a return engagement between efficiency and size in the assembly.
Court = 1000uF.
470uF Cin is stable.
D is chosen SB5100 or similar model that supports current 5A.
As p-channel MOSFET IRF9530 is used to support currents up to 12A constant.

Measuring Circuits
Battery Voltage:

The charging voltage is monitored using a voltage divider to measure the difference voltage between the positive and negative of the battery. For the measurement range of the charger is (3V to 20V charge voltage), are chosen with appropriate values of resistors. When the voltage exceeds the reference voltage (5V), the voltage is divided with two reading to locate resistance in the range (0-5v).
R1 = 18kΩ
R2 = 56kΩ
Vp = R1 / (R1 R2)
Vp = 0.2432
5V / 1024 = 4.88mV steps / step.
N = 4.88 / 0.2432 = 7.20 mv / step.
This value of N gives the upper limit of reading the battery:
Vmaxbat = 7.20 * 1024 = 20555.56 steps mv = 20.5v .-

charge current
The charge current is measured by sensing the voltage on a shunt resistance of 0.1Ω. This voltage is amplified using an operational amplifier - configured as noninverting for charing andr for the measurement of discharge current - to improve the accuracy of the measurement before powering the A / D converter of the microcontroller.
This voltage is amplified by the factor:
R1 = 3.3kΩ
R2 = 19kΩ
Amplification factor
F = 1 (R2/R1) = 6.76
The amplifier output voltage is:
Vibat = (1 (R2/R1)) * = 6.76 Ishunt Ishunt
The maximum current that can be measured is:
IBAT = 4.88 / 6.76 Ishunt = 7.2257 A
This gives us a resolution:
7226 mA / 1024 steps = 7.06 mA / step

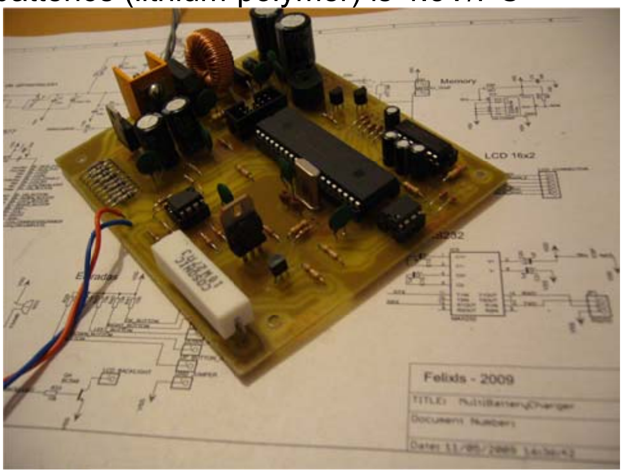
Description of the charging methods

1. Fast charge current: 1CmA (quick charging temperature: 0 C to 40 C). To achieve control and stop the fast charge, we recommend charging more than 0.5CmA but less than 1CmA. Charging batteries over 1CmA can cause active ventilation security by increasing the internal pressure of the batteries, causing leakage of electrolytes. When the battery temperature is detected by a thermistor or other sensor, and temperature is below 0 C or above 40 C at the beginning of the charge, a charge must be done floating, rather than a fast charge. Quick charge should be stopped when either values described below reaches the level indicated:
• Control of the upper limit voltage: Approx. 1.8V/celda. This method of charge changes to float if the battery voltage reaches approximately 1.8V/celda because problems or malfunction of some kind.• value of dV / dt (or delta peak cut): 5 to 10mV/celda. When the voltage battery drops from its peak by 5 to 10mV/celda for fast charging is to be stopped, andthe charging method should be changed to float.

• Value of dT / dt (or cutout): 1-2 C / min. When an increase in battery temperature per unit time is detected in the thermistor or other temperature sensor for fast charging, and the temperature rise is detected the sensor fast charging should be stopped and the charging method changed to floating.

• Time limit: 90 minutes.
2. To charge excessively discharged batteries, first applied for the float charge current to flow, and then proceed with rapid charging once the battery voltage rose.
Initial fast charge voltage: Approx. 0.8V/celda with a current of 0.2 ~ 0.3 MAC.
Requirements:
• Initial Wait: 10 minutes. This prevents detection circuitry dV / dt is activated for the time specified at the beginning of the fast charge. However, the detection dT / dt can be active in this period. This is necessary to batteries that were left without charge for too long or were discharged, and so on. This initial charge is expected and necessary to stop charging (to prevent malfunctions)because pseudo -dV/dt.
• Current maintenance or floating: 0.033 to 0.05 MAC. When the current flow is high, the battery temperature increases, causing the characteristics battery deterioration.

• Fast-charge time: 60 minutes.
• Total time: 10-20 hours. Overcharing a battery Nixx, even floating charge or maintenance, cause a deterioration in the characteristics of the batteries. To prevent float charge overhead or any other method, you must provide a timer to regulate the total charge time.
Analysis of charge / discharge of batteries SLA (Sealed Lead-Acid) Lead-Acid
Unlike Nixx batteries, such batteries are charged to fixed voltages instead of fixed current.
Charging Method:
1. Check if the battery will accept the load.
2. If OK, start the constant current charging capacity C/10.
3. When the voltage reaches 2.55V/PC switch to constant voltage load 2.45V/PC.
4. If the current falls below capacity C/20 then switch to float charge.
5. Charing of floating indefinitely 2.25V/celda (recommended maximum 20 hours).
Requirements:
An SLA battery should not be discharged unless above 1.5V/PC.
Maximum voltage battery is 3V/PC SLA.
Analysis of charge / discharge of batteries LiPo (lithium polymer) and LiIon (lithium ion)
Charging Method:
1. Constant current to 1C until the voltage reaches 4.2V/PC
2. 4.2V/PC constant current until the current drops to the capacity / 15.
3. Floating load capacity / 30 for 30 minutes.
Requirements:
A LiPo battery should not be discharged unless 2.5VPC.
Maximum voltage for LiPo batteries (lithium polymer) is 4.5V/PC



Technical Data:

Maximum charge current: 0 to 5A
Maximum discharge current: 1A (I = V / R -> R = 12/10 -> I = 1.2A)
Modes: 0: NiCd, 1: NiMh, 2: SLA, 3: LiPo, 4: LiIo
Battery capacity: 3000mAh
Number of cells: (1-19) 6
Charge: (1-10) (10) -> 3000 * 1.0 = 3A
Discharges: 0 to 1A
Delta expects peak: 10 minutes
Minimum temperature
high currents (> 0.5C) 10 degrees
Court by low voltage (cell):
NiCd (0-2550) 800mV
NiMh (0-2550) 1000mV
LiPo (2500-3500) 3000mV
SLA (1500-2500) 2000mV
Delta peak (0-255):
NiCd 40mV
NiMh 20mV
Maximum voltage per cell:
NiCd 1680mV
NiMh 1680mV
LiPo (3500-4500) 4200mV
SLA (2000-3000) 2500mV (2.5V x 6 cells = 15V - v. maximum SLA 12V)
Normal charging voltage per cell:
LiPo (3500-4500) 4200mV
SLA (2000-3000) 2450mV (2.45V x 6 cells = 14.7V)
Final current (% of initial charging current):
LiPo (3%) -> 3000 * 3 / 100 = 90mA
SLA (5%) -> 3000 * 5 / 100 = 150mA
Timeout
NiCd and NiMH 65 min at 1C, 130 min 0.5C
30 min by floating LiPo
SLA 25 hours